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ANTENNA ANALYSES: OBJECTS NEAR ANTENNAS AND MICROSTRIP ANTENNAS--ETC(U)  
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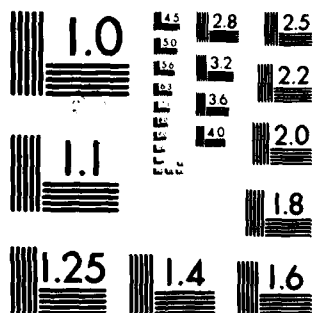
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6 ANTENNA ANALYSES: OBJECTS NEAR ANTENNAS AND MICROSTRIP ANTENNAS.

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10 CHALMERS M. BUTLER

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) In this report is presented a description of the research and accomplishments achieved under Grant DAAG29-76-G-0285 from the U. S. Army Research Office to the Department of Electrical Engineering, University of Mississippi. The research work encompassed two classes of antenna analyses. One was an investi- gation of the effects of a nearby object upon an antenna and its performance and the other was a study of the center-fed, circular microstrip antenna.		

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## FOREWORD

This is the final report of research accomplishments by the Department of Electrical Engineering, University of Mississippi, under the sponsorship (Grant DAAG29-76-G-0285) of the U. S. Army Research Office. This report contains a brief description of the problems investigated, a summary of the analysis and findings, a list of participants in the work with an indication of a degree earned, and an appendix listing the publications resulting from the research effort.

## PROBLEMS INVESTIGATED

In this investigation, two classes of antenna analyses were performed, both being based upon the formulation and numerical/analytical solution of integral equations. In one phase of the study, the effect of a nearby object upon the performance of a wire ("whip") antenna was investigated. Numerous nearby objects were considered, including one which crudely represented electromagnetically a human being and others which might represent bodies that could strongly degrade antenna performance. In the other phase, a radial, parallel-plate waveguide with an annular slot in its upper plate was analyzed. This structure is of interest in itself and, in addition, with a sufficiently wide slot, its behavior replicates that of a circular microstrip antenna providing one a tractable model upon which to base a theoretical analysis of the microstrip radiator.

## ANALYSIS AND FINDINGS

### Antenna with nearby Object

In the first phase of the research work, an analysis of a thin-wire antenna in the presence of a sphere was undertaken. The results of this analysis enable one to assess the influence of the presence of a nearby object upon the operating characteristics of an antenna. Even though the object is taken to be a sphere for analytical expediency, the data are of value to those who must consider antennas radiating in the vicinity of general objects. An integro-differential equation was formulated for the total axial current  $I$  on the thin-wire antenna and this equation was solved numerically. The kernel of the equation includes a dyadic Green's function which accounts for

the presence of the sphere and which was carefully developed for either a perfectly conducting sphere or a general sphere of material ( $\mu_b, \epsilon_b$ ), where  $\epsilon_b$  can be taken to be complex to account for losses. Input admittance of the monopole in the presence of the sphere was computed from knowledge of  $I$  and, for the special case of a nearby conducting sphere, was corroborated by means of measured results. Radiation patterns for the antenna/sphere structure were determined from computations. It was found that the presence of the sphere significantly affected the input admittance and also the radiation pattern of the wire/sphere structure.

With confidence gained from the study of the problem of the sphere near the wire antenna, the investigators next undertook the more difficult problem of determining the influence on the characteristics of a thin linear antenna due to the presence of a nearby perfectly conducting body of revolution (BOR). In practical applications antennas often are located near other conducting structures, many of which may be approximately modeled as bodies of revolution, and it is therefore desirable to be able to analyze such configurations accurately in order to design a system for optimum performance. The close proximity of a BOR to a radiating antenna may have a significant effect on antenna properties such as input impedance and radiation pattern. The resonant frequency of the antenna may even be altered. Many practical structures may be modeled as bodies of revolution. For example, a missile may be modeled as a cylinder with a conical or spherical cap, a satellite as a closed cylinder or sphere, a spacecraft re-entry vehicle as a truncated cone topped by a cylinder, a smokestack as an open-ended cylinder, etc. The presence of the body was accounted for by a numerical, dyadic Green's function and the modified wire equation was solved by numerical techniques to obtain the current distribution on the wire. The effects of various bodies on input admittance were compared with results for an isolated antenna. Measured and theoretical input admittance data for a monopole near several different bodies of revolution were found to be in good agreement. It was found that the nearby body influenced the antenna admittance significantly. Shape, size, and orientation of the body relative to the antenna were found to be important.

The above analysis was extended to the case in which the BOR was of lossy material and of the (rough) shape of a human being. The numerical



procedure for solving the equation for current on the wire near the lossy body of revolution became very complex and involved extensive computer programming and time. Acceptable results were obtained for the antenna near the "man" but the cost in computer resources and the limitations of computing facilities here at the University of Mississippi forced the investigators to greatly reduce the scope of this part of the study.

During the course of the investigation described above, a useful alternate form was discovered for the traditional thin-wire equations. The free space Green's function of electromagnetics was transformed to a form which simplifies analyses of general wire structures. The useful property of the new form is that it enables one to compute the electric field component  $E_s$  by applying only  $\left(\frac{\partial^2}{\partial s^2} + k^2\right)$  to a potential integral (with new Green's function) even though such integral is, in general, to be taken over currents that are not s-directed. It can be shown that the transformation effectively yields  $E_s$  in terms of a TM representation.

#### Microstrip Antenna

In the second phase of the research work, attention was devoted to the microstrip antenna. The investigators studied the circular disk microstrip antenna from the viewpoint of aperture theory and, in addition, performed computations of radiation admittance at the edge of a straight-sided microstrip antenna.

To gain knowledge of the microstrip radiation admittance, an analysis was performed on a parallel-plate guide with a very wide slot in its upper plate. For a sufficiently wide slot, the slotted guide with truncated dielectric is a good model for the rectangular microstrip insofar as computation of the edge-radiation admittance (per unit length) boundary condition is concerned. Results obtained from this model are improvements upon the approximations employed heretofore.

In the case of the circular microstrip antenna, an accurate model was developed and analyzed. The center-fed circular microstrip was viewed as a coax-driven radial waveguide terminated in an aperture. An integral equation was formulated and subsequently solved numerically for the aperture electric field. From knowledge of the aperture electric field, the load on

the coax-to-radial-guide junction was computed as was the field radiated by the structure. Rather extensive data have been compiled for this problem and the investigators continue to study it.

#### GRANT PARTICIPANTS

The principal participants in the research work supported by the grant from ARO were Dr. C. M. Butler and Mr. T. L. Keshavamurthy, with Dr. T. K. Wu and Dr. A. W. Glisson being employed during portions of the grant period. Dr. L. L. Tsai was to have served as co-principal investigator but was unable to do so because of illness and subsequent untimely death due to cancer. Dr. C. E. Smith replaced Dr. Tsai for a very short period of time but his participation was interrupted by serious illness. Two graduate students, Mr. G. Hale and Mr. S. Singarayar, were employed by the project for short periods.

Mr. T. L. Keshavamurthy is expected to receive the Ph.D. degree in August, 1980. His Ph.D. thesis will result directly from part of the research work supported by the grant.

## APPENDIX

### Publications and Presentations

#### Resulting from Research Supported by ARO

1. The following papers have been published in journals and proceedings.
  - A. Butler, C. M., and E. K. Yung, "Analysis of a Terminated, Parallel-Plate Waveguide with a Slot in Its Upper Plate," Annales des Télécommunications, Vol. 34, Nos. 9-10, pp. 451-458, Sept.-Oct., 1979.
  - B. Butler, C. M., and D. R. Wilton, "A Transformation of the Free Space Green's Function with Applications to Analysis of Wire Structures," IEEE Trans. Antennas and Propag., Vol. 28, No. 1, pp. 108-111, Jan., 1980.
  - C. Butler, C. M., "Analysis of a Coax-Fed Circular Microstrip Antenna," Proceedings of the Workshop on Printed Circuit Antenna Technology, Physical Science Laboratory (Sponsored by Army Research Office), Las Cruces, NM, pp. 13-1 - 13-17, Oct., 1979.
  - D. Keshavamurthy, T. L., and C. M. Butler, "Analysis of a Finite-Width Slot in the Upper Plate of a Parallel-Plate Waveguide Having a Truncated Interior Dielectric," Proceedings of SouthEastCon '80, pp. 252-255, Nashville, TN, April, 1980.
  - E. Butler, C. M., and T. L. Keshavamurthy, "Analysis of a Wire Antenna in the Presence of a Sphere," IEEE Transactions on Electromagnetic Compatability, Vol. EMC-22, No. 2, pp. 113-118, May, 1980.
2. The following paper has been accepted for publication.

Glisson, A. W., and C. M. Butler, "Analysis of a Wire Antenna in the Presence of a Body of Revolution," IEEE Trans. on Antennas and Propag.
3. The following paper has been accepted for presentation and publication in the proceedings of the meeting.

Butler, C. M., and T. L. Keshavamurthy, "Analysis of a Parallel-Plate Radial Waveguide Having an Annular Slot in its Upper Plate and Being Fed by a Coaxial Guide," International U.R.S.I. Symposium 1980 Proceedings, Munich, Federal Republic of Germany, August, 1980.
4. The following papers have been submitted to journals.
  - A. Keshavamurthy, T. L., and C. M. Butler, "Characteristics of a Slotted Parallel-Plate Waveguide Filled with a Truncated Dielectric," IEEE Transactions on Antennas and Propagation (submitted to).

- B. Butler, C. M., and T. L. Keshavamurthy, "Investigation of a Radial, Parallel-Plate Waveguide with an Annular Slot, Radio Science (submitted to).

5. The following papers have been presented at professional meetings:

- A. Wu, T. K., and C. M. Butler, "Numerical Green's Function for Dielectric Bodies of Revolution and Its Applications," USNC/URSI Meeting, Boulder, Colorado, January 1978.
- B. Butler, C. M., and D. R. Wilton, "A New Formulation for the Analysis of Thin-Wire Structures," Joint IEEE AP-S International Symposium and USNC/URSI Meeting, College Park, Maryland, May, 1978.
- C. Butler, C. M., and T. Keshavamurthy, "Analysis of an Arbitrarily Oriented Thin-Wire Antenna in the Presence of a Conducting Sphere," National Radio Science Meeting (USNC/URSI), Boulder, Colorado, November, 1978.
- D. Wu, T. K., and C. M. Butler, "Analysis of the Man-pack Radio Antenna above Ground," National Radio Science Meeting (USNC/URSI), Boulder, Colorado, November, 1978.
- E. Glisson, A. W., and C. M. Butler, "Investigation of an Arbitrarily Oriented Thin-Wire Antenna Near a Body of Revolution," National Radio Science Meeting (USNC/URSI), Boulder, CO, Nov., 1979.
- F. Butler, C. M., and T. L. Keshavamurthy, "Analysis of an Annular Slot in a Parallel-Plate Waveguide Excited by a Radially-Travelling TEM Wave," National Radio Science Meeting (USNC/URSI), Boulder, CO, Nov., 1979.

5. The following papers have been accepted for presentation.

- A. Butler, C. M., and T. L. Keshavamurthy, "Analysis of a Coaxial to Radial Waveguide Junction," National Radio Science Meeting (URSI) Quebec, Canada, June, 1980.
- B. Keshavamurthy, T. L., and C. M. Butler, "Analysis of an Annular Slot in a Radial Waveguide with an Interior Truncated Dielectric," National Radio Science Meeting (URSI), Quebec, Canada, June, 1980.

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